re ACT

Project Manual

University of Maryland

Project Overview

re ACT, the University of Maryland's (UMD) U.S. Department of Energy Solar Decathlon 2017 entry, features a central integrating spine that transfers and transforms various forms of "waste" into useful resources balancing: earth/sky, wet/dry, mass/void, inside/outside and core/courtyard, etc. in a yin/yang manner. This central zone of integration, connects internal flows within the house, harvesting and repurposing excess and storing and transferring to meet changing needs. This N/S core/courtyard spine separating the public spaces from private, is bisected by an E/W corridor, a liminal space through which occupants traverse between the inner and outer selves. The core and courtyard are among the most evidential features of *re ACT*, providing both utility and service while offering generous, open and dynamic space. Though technically separate, they function together to advance the entire building as more self-sustaining.

The core is made up of the essential mechanical, electrical, waste and water systems linking mechanical functions from back to front and from above and below in a single, fully accessible *chassis wall.* A fully integrated, predictive and automated *smartHouse* data collection and control system package will enable residents to follow, learn from the data it collects, generating cost and resource savings, reducing environmental impacts, and even providing regenerative benefits. Sensors and predictive data in terms of weather forecasts and user profiles will influence the way in which the control system interacts with power, HVAC, waste, and water. While performing necessary calculations, controls will interpret, and offer options for *re ACT* residents to learn from and offer guidance through an interactive touch screen tablet. The intuitive user interface will provide automatic/human schedule optimization options, displaying data on power, water, and other resources produced/bought/sold predicted, movable events corresponding to major activities and a predicted schedule such as weather forecasts. The actual imbedded system controllers are modular, capable of being accessed, independently upgradable as new technologies become available, and are able to be implemented in many different architectural configurations.

The courtyard has a strong visual and physical connection both to the outside and inside worlds. It serves as a bridge between the two environments performing many important functions, such as meditating temperatures by finding and circulating cool/dry/clean air throughout the house in warmer months, and in the winter, finding and circulating humid/warm/clean air using the greenhouse to collect and expel as needed. The courtyard will also be used to support plants, for diverse aesthetic, nutrient and other functional benefits, for example, providing beauty, growing food, converting carbon dioxide into oxygen, or filtering water. These elements provide visual appeal to almost all corners of the house and will integrate year-round nature into residents' daily lives. Although not technically included in the habitable or climate controlled square footage of the house, the courtyard acts as a "bridge season" extension of the living space, extending the benefits of fall and spring, while diminishing the less desirable impacts of hot summers and cold winters. These added functions will expand the range of social activities and will serve as a sanctuary or escape from the normal constraints of a house. A fully open roof and doors will be able to provide, either actual outdoor experiences into the heart of the house, or create more idealized conditions during inclement weather. Retractable shading fabrics at the ceiling plane in the courtyard will provide full or partial shade when desired. In order to fully utilize the courtyard space, residents will be able to open sliding doors between the courtyard and both the public and private zones of the home. This also promotes the house as a more open, and flexible environment for entertainment or simple spaciousness. The operable windows, doors and roof will allow the residents to open the house up to the elements, while shielding the actual house from losing energy and thereby improving efficiency.

re ACT has an ambitious goal of accelerating the transformation of the residential construction industry. The team will work with a chosen influential industrial leader by leveraging the research and development investments it has made in its Solar Decathlon entry, and by bringing to the negotiation table a ready and interested market in their particular offering. This interest isn't in the single or literal Decathlon home to be featured in the 2017 competition, but in its prototypical "DNA" and flexible configurations. By working with industry leaders and by developing market "off-takers," Maryland intends to generate greater industry investment (by paying forward) and willingness to collaborate, in exchange for contractually sharing in the fruits of a substantial market segment. Maryland this time around is seeking an ongoing, or sustainable funding program for its ongoing research and development of ideas, systems and innovations to serve the future of the housing industry. *re ACT* is positioning itself to accelerate the housing industry's embrace of the Living Building Challenge goals of Red List avoidance, Responsible Industry and Net Zero Waste. These goals are intended to create a materials economy that is non-toxic, ecologically restorative, transparent, and socially equitable. Furthermore, *re ACT* will serve as a seminal and flexible prototype for housing that is more readily adaptable to a diverse range of clients, communities, construction technologies and ecological environments.

Part of the strategy to ignite a paradigm shift is the choice of *re ACT's* target market of two separate Native American tribes, specifically the White Mountain Apache Navajo Tribe in Bylas, Arizona and the Leech Lake Band of Ojibwe in Chisholm, Minnesota. Native American tribes have long faced challenges in providing safe, decent, and affordable housing for tribal members. Recognizing the extreme housing needs in many Native communities, the vulnerability of reservation land to climate change, *re ACT* will use sustainability and regenerative design principles to promote quality of life and culture by focusing on sustainable construction, specifically techniques and technologies that make homes more energy efficient and healthy while respecting Native American cultural heritage. Solar energy using direct current is particularly relevant as tribes tend to face high energy costs because of their remote locations.

Instructed by the successes and best practices used by the Sustainable Native Communities Collaborative (SNCC), *re ACT* will embrace emerging sustainable building practices that promise to transform and support tribal housing projects already underway. The case of the Pinoleville Pomo Nation Homes (PPN) demonstrates that tribes with access to technical assistance and control of their own financing can achieve green, culturally appropriate housing even after years of being marginalized. Tribal leaders are increasingly seeking sustainable housing and renewable energy power systems that utilize sustainability best practices, renewable energy technology, to provide their communities with cultural renewal, self-sufficiency, economic opportunity, and sustainable returns on investment (ROI) that compliment tribal culture. In the case of PPN, the renewable energy-efficient systems were co-designed and built by tribal citizens providing jobs. Rainwater catchment and grey-water systems reduced vulnerability to water shortages and support on site plantings. The University of California Berkeley provided technical assistance through the Center of Community Assessment of Renewable Energy and Sustainability (CARES).

re ACT is working within the Solar Decathlon framework (sustainability expo, educational events, professional development and consumer workshops) to achieve similar results and, as an outreach goal, to find opportunities to mindfully facilitate the tribal embrace of and desire for sustainability and self-determination. The *re ACT* goal is to develop technologies and diverse design concepts and prototypes that will empower residents to live more independent affordable lifestyles while promoting comfort, awareness and beauty. *re ACT* will offer opportunities for tribal families to incrementally build larger and more technologically advanced infrastructures and features into their evolving homes. For example, by offering and adding multiple interactive energy-efficient systems, and interactive *smartHouse* control system, solar photovoltaic arrays, composting toilets, dual-barrel composting, grey-water irrigation, and rain-catchment systems, families can build both greater equity and capability into their homes as time and resources allow. The renewable energy systems will reduce dependence on outside service providers and demonstrate a tribal preference for clean and renewable energy. The *re ACT* prototype is designed to conserve resources with passive and active heating and cooling considerations and green, mold- and pest-resistant wall prototypes. Rainwater-catchment, rainwater reuse with potable water generation, and grey-water systems will help reduce vulnerability to water shortages and support on-site gardens and landscaping as well as an inside hydroponic system to be able to grow food indoors.

re ACT advances a design built on developing homes as kits of interactive and disentangled systems parts that can be efficiently manufactured, transported, assembled and unassembled. The kit of parts is conceived as an effective new high performing combination of ingredients able to be arranged or configured into diverse and clearly differentiated building sizes and forms. It is clear that the White Mountain Apache Navajos in Arizona, the Leech Lake Band of Ojibwe in Minnesota, the Solar Village in Colorado and the University of Maryland campus in Maryland are in dramatically different biomes, so the prototypical *re ACT* designs will need to respond to diverse local climates, building material supply chains, and other cultural variables. The *re ACT* vision is to delight in exploring the design implications of a more easily expanding and contracting home to better accommodate family fluctuations and transformations and even to be able to aggregate homes into greater density and efficiency. The *re ACT* team is creating not just one prototype but a family of house and housing types based on reconfigurable and regenerative design principles, facilitating variations in size, material finishes, and layout configurations to meet the diverse and dynamic needs of a real community. The team is seeking to influence the manufacturing partner to develop production plants in close proximity to tribal lands, to contribute to expanding training and economic opportunities for members of the tribal community.

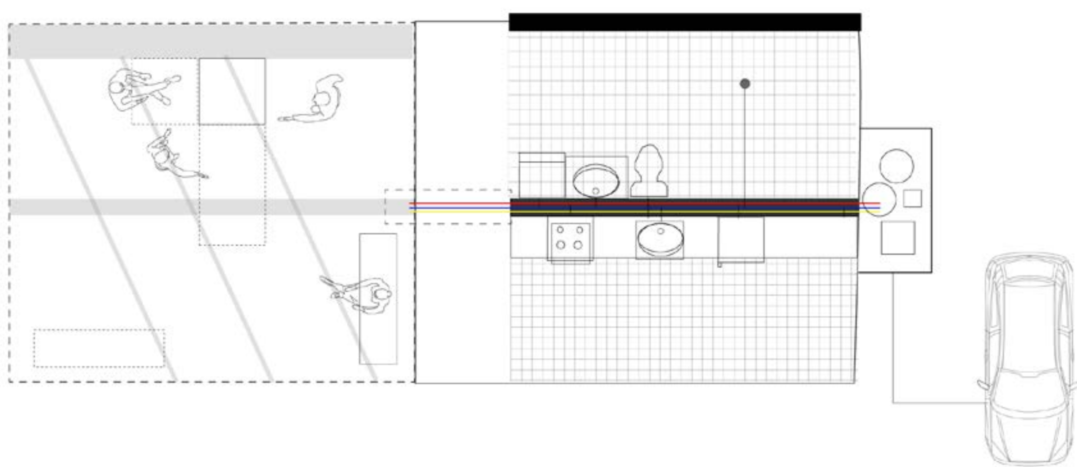
Working in partnership with industrial and component manufacturing pioneers, the *re ACT* team will be exploring strategies for developing new commercially available products and supply system innovations which can become market ready, environmentally sensitive, and cost effective.

re ACT will also demonstrate the affordability of Living Buildings and Communities when life cycle costs of utilities like water, clean electric power and waste management and repurposing are included. We realize the consideration of the true and total costs of development must be factored in building an authentic sustainable future. Students and faculty, working in collaboration with professional tradesfolk, will focus on quality, efficiency and craft in construction of the *re ACT* prototype. Assembly, standardization, and flexibility of components, along with an intrinsic disentanglement (to better "future proof" home building) of systems and their interdependence will be among the strategies the *re ACT* team will employ to increase build-ability, reduce construction and transportation costs, and to facilitate changes and/or upgrades over time.

It is not an overstatement to say that addressing climate change is today's most pressing cultural, political, technical and scientific challenge. As a Land-Grant University, UMD is committed to championing ideas that drive the discovery and dissemination of new knowledge in order to solve the most vexing challenges of the present. The Solar Decathlon is living proof that bright minds can change our world for the better. *re ACT* has garnered a campus-wide multidisciplinary response to the Solar Decathlon 2017 call for outreach and education that will accelerate the adoption of energy-efficient design and products to combat the effects of the built environment on nature and ecosystem. Moreover, Land-Grant institutions have a mission to provide access to the education and opportunity necessary of citizens to shape their own destinies. UMD believes it must contribute to solutions and progress through education, joint research, student/faculty exchanges, and collaborative problem solving. *re ACT's* outreach to our target tribal market is intended to engage tribal Land-Grant colleges in service to this mission. By blending design excellence and smart energy production with innovation, market potential, and energy and water efficiency, *re ACT* embraces the role of catalyst to ignite a paradigm shift in the residential building industry.

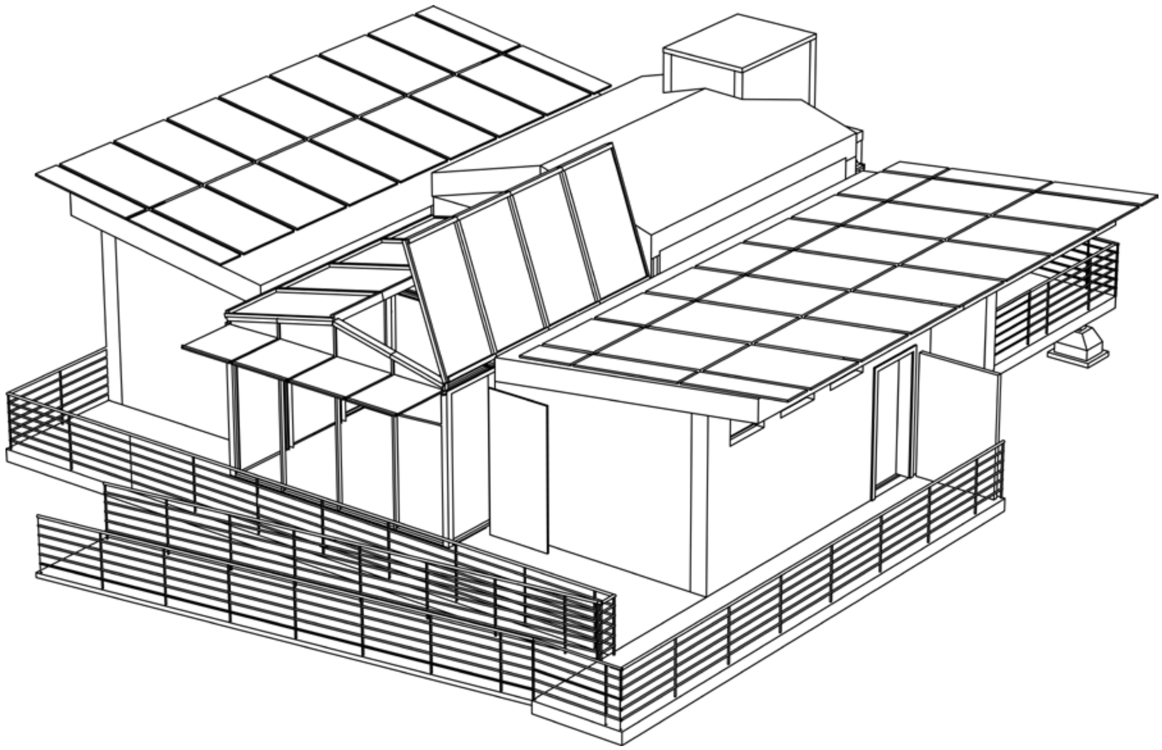
Reconfigurable Features

In 2017, the University of Maryland will demonstrate architectural design and technologies that take maximum advantage of both active and passive solar strategies. The heart of the house will be the Core and Courtyard combination. The Core contains the active components including charge controller, batteries, water filtration, heating and cooling systems. The density of the Core is maximized to facilitate efficient use and reuse of energy, including waste heat, water and nutrients. Adjacent to the Core is the Courtyard, intended not only as the social hub of the home, but also as a passive solar collector and nursery for plants.

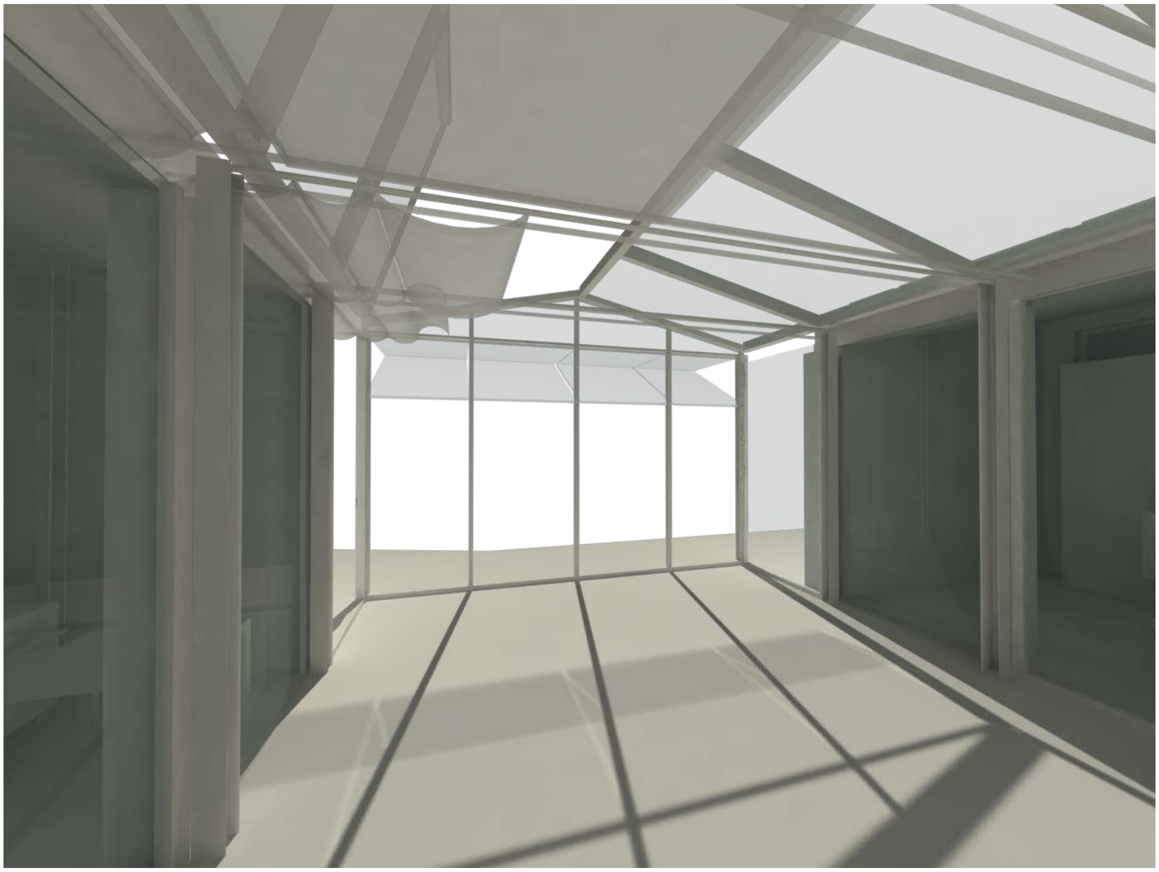


Courtyard

In order to provide maximum benefit in all seasons, day and night, the Courtyard must be flexible, harvesting solar heat when it is available, storing it until needed and then distributing it. In the summer, the Courtyard will serve as a breezy shaded spot to escape the intense Denver sunshine during the day, and a sheltered spot during cool nights under the stars. The Courtyard must open and close, much as a flower does. It is essentially a greenhouse with walls and roof designed to close tight or open completely as needed.



Below the glazing, roll-out shades will provide protection from the sun when needed. The baseline design for the actuating mechanism will be mechanical linkages connected to a single crankshaft per leaf and controlled manually, reusing either beautiful vintage hardware from old commercial greenhouses or custom designed special hardware reflecting the crafted sensibilities of the home.



The Courtyard will be configured appropriately throughout each day during the Competition, depending on weather conditions. Changes in weather may require reconfiguration during public tour hours, and all appropriate safety precautions will be taken during these operations. A full description of the Courtyard's function and reconfiguration options will be included in the materials submitted in advance to the Juries.

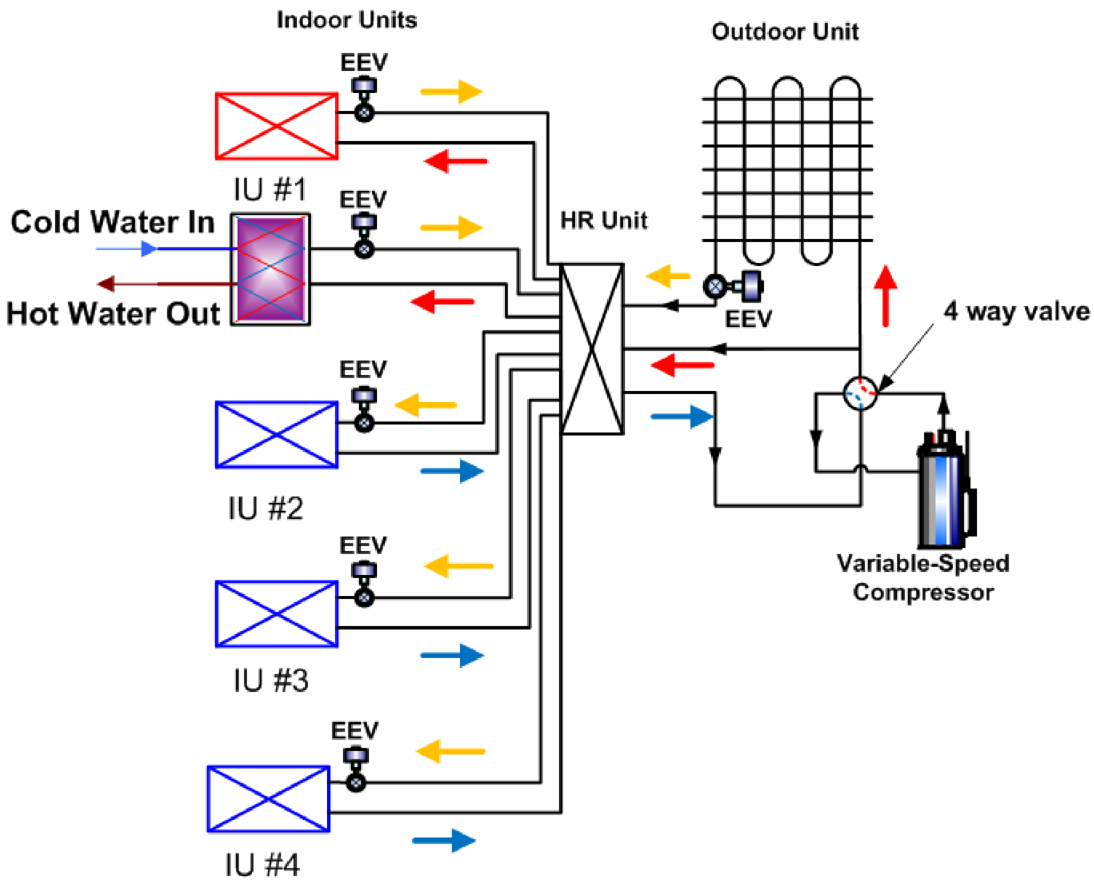
Core

The Core is also designed to harness the power of the Sun in different ways, depending on the needs of the residents. The Attic of the Core is a zone where solar heat can be employed by various *appliances* that can be used interchangeably.

- automatic slow cooking solar oven
- solar food dehydrator
- clothes drying rack
- dish drying rack

Operation of these various features will be demonstrated as required by the Rules during the public tours and Jury walk-throughs.

The HVAC system housed in the Core is designed to be reconfigurable also, capturing waste heat from various components (such as the oven, dishwasher, clothes dryer and refrigerator) and storing that energy in the hot water tank for later use. Depending on exterior conditions, heat may be drawn from the attic or courtyard to maximize thermal efficiency of the system.



Advanced Adaptive Controls

Maryland's house will also be prescient to changes in the weather, and will adapt itself preemptively. The Model Based Controller (MPC) will collect weather predictions from the Internet and adjust the operation of the house to provide optimum comfort and efficiency. If a cold night is predicted, it will recommend reconfiguration of the Courtyard to collect and store heat for the evening. If rain is predicted, it will adjust the operation of the water harvesting and reuse system to take advantage of that resource. This automated assistant will help the residents make the best use of their advanced regenerative dwelling. The architecture of this system will be hierarchical and decentralized so that subsystem controllers provide basic autonomic control of each component while the MPC focuses on managing resources and adjusts the set-points of the subsystems accordingly.

The operation of the MPC will be demonstrated during all public tours as well as for the Juries.

Energy Analysis

For its entry into the 2017 Solar Decathlon competition, the University of Maryland has created a design integrating passive strategies for heating and cooling with advanced technology. The team's goal has been to advance the state of the art in residential energy systems while still relying primarily on commercially available components. Among the innovations being explored are a reconfigurable sunspace (the Courtyard), appropriately scaled VRF systems, and a Model Based Control (MPC) system. These advances require high-fidelity energy modeling.

To best accommodate its workflow and pedagogical setting, Maryland decided to take a multi-path approach using multiple tools. Initial parametric studies were conducted using the BEOpt tool developed by the National Renewable Energy Laboratory (NREL). This tool offers an easy to use interface, a large library of built in components and options, and a cost-based optimization engine. The output interface allows users to compare the results of multiple simulations in order to select features and options that best meet their goals. This tool is limited, however, in how closely it can model non-standard window distributions, roof shapes and features like sunspaces.

The next layer of analysis was conducted using Revit's Green Building Studio (GBS) software, as well as the OpenStudio tool and Energy Plus. These tools require greater user expertise but allow the modeling of more complex and specific designs. Even so, these tools are not designed to model complex reconfigurable spaces like Maryland's Courtyard feature. Analyzing features like this required the development of new models and integration with the existing simulation tools. This work is still ongoing. Maryland's house will use energy simulations not only for design, but also for operation of the house in real time. In parallel with the analytic studies described above, the Automation Team is developing a virtual house that can be used to predict the performance hours or even days ahead of time, allowing strategic operation of the building's passive and active systems to maximize comfort and optimize energy use. This Model Based Control (MPC) capability is being built using the Python computer language. It will include an interface for downloading weather information from the Internet, real-time input from sensors, and a user interface to facilitate management of systems and resources by the residents.

Parametric Modeling – BEOpt

BEOpt was used to explore different options through many successive parametric runs. Many different factors including window to wall ratio, R-value of the walls and roof and floor, and assumed infiltration rate were studied using this model. These factors were also considered in terms of their impacts on architectural expression and site development strategies. Ultimately, these studies led to the configuration described below.

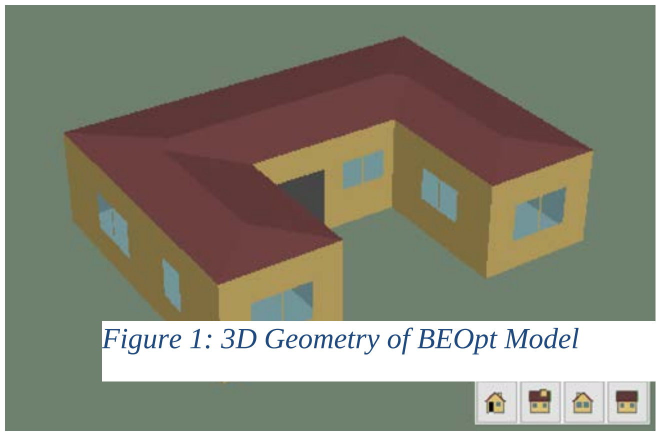


Figure 1: 3D Geometry of BEOpt Model

This is a basic representation of the house geometry in the current proposed U-Shape. After parametric studies were completed, the following table presents the final configuration for this model.

Table 1: BEOpt Model Parameters

Parameter	Value
Finished Floor Area	960 sqft
Bedrooms	4
Bathrooms	1
Orientation	South
Double Wood Stud	R-45 Fiberglass, Gr-1, 2x4 Staggered, 24 in o.c.
Wall Sheathing	OSB-with-Rockwool
Exterior Finish	Wood, Light
Finished Roof	R-64, SIP
Roof Material	Metal, Medium
Crawlspace	Uninsulated, Unvented
Interzonal Floor	R-30 Cellulose, Gr-1
Carpet	0% Carpet
Floor Mass	2 in. Gypsum Concrete
Exterior Wall Mass	5/8 in. Drywall
Partition Wall Mass	5/8 in. Drywall
Ceiling Mass	5/8 in. Drywall

Window Areas	323 sqft
Windows	Low-E, Double, Insulated, Air, M-Gain
Interior Shading	Summer = .5 , Winter = .95
Door Area	48 sqft
Doors	Fiberglass
Overhangs	2ft, First Story, Back Windows
Air Leakage	1 ACH50
Ventilation	ERV, 72%, 2010 ASHRAE 62.2
Mini-Split Heat Pump	SEER 14.5, 12 kBtuh/unit
Water Heater	HPWH, 50 gal
Lighting	100% LED
PV Panels	10 kW

The energy consumption breakdown and results are shown, with the final configuration inputs.

Table 2: Energy Consumption

Source	Energy Use (MMBTU/Year)
Misc. (E)	5.63
Vent Fan (E)	4.61
Lg. Appl. (E)	17.5
Lights (E)	5.9
Cooling Fan/Pump (E)	0.08
Heating Fan/Pump (E)	0.36
Cooling (E)	6.01
Heating (E)	21.99
Heating, Suppl. (E)	3.55
Hot Water (E)	5.71
Hot Water, Suppl. (E)	3.06
Total	74.4
PV	134.9
Net (Total - PV)	-60.5

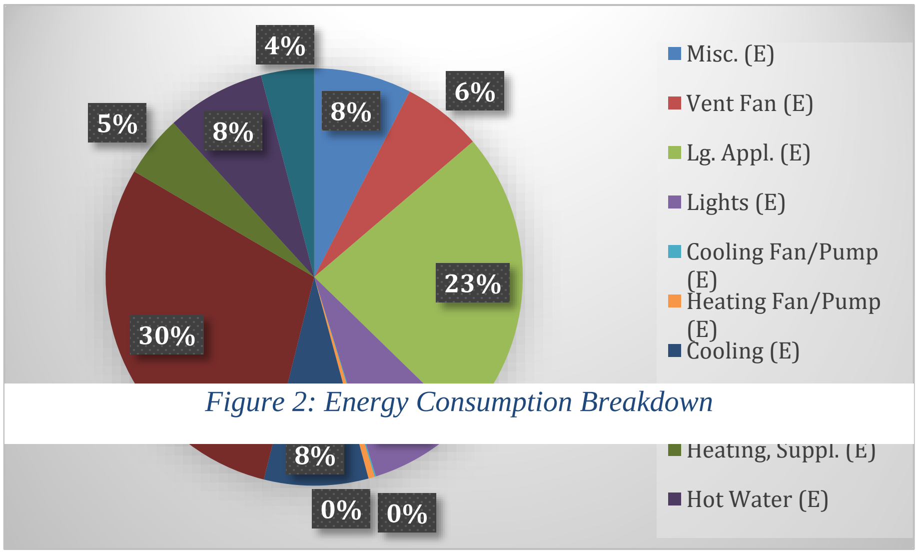


Figure 2: Energy Consumption Breakdown

Modeling the Courtyard

Perhaps the most important architectural feature of the Maryland house is the Courtyard, which takes the form of a greenhouse or sunspace. The potential of this space not only to energize the social life of the house but also to serve as a reconfigurable passive solar collector was one of the driving concepts behind the overall design for the house.
BEOPt and most other modeling tools do not support the analysis of sunspaces, and so the Energy Modeling Team had to develop this model from scratch. The basic formulae used to model the space were found in the literature (1), and are summarized below.

The courtyard model includes 10 control volumes: South wall, North wall, East and west walls in contact with conditioned space, East and west walls in contact with outside, Eastwards and westwards tilted roof, Air and floor. Modelica Buildings Library and components from Modelica Standard Library – Thermal Package were used for the model with some custom components developed. TMY3 weather data for Denver International Airport is used as input using the Weather Input block.
For glass covers the energy equation can be written as:

$$\rho_g c_g \frac{dT_g}{dt} = q_a^r - q_e^r + q_i^{co} - q_o^{co}$$

Where ρ is the density, c is the specific heat capacity, T is the temperature of glass, t is time, the subscript g refers to glass. Right hand side has four heat flux (q) terms with superscript “r” referring to radiative heat transfer while “co” to convection. Subscripts for radiative heat flux a is absorbed, e is emitted, while for convective terms “i” is for inside space while “o” is for outside space.

Constant heat transfer coefficients are given as inputs for convective heat transfer obtained by averaging the parameters from the empirical relations reported in [2]. For radiation absorbed from sun by each glass surface, dot product of direct normal radiation coming in at solar hourly angle and the glass surface normal is calculated. This is then multiplied by glass surface area and absorptivity to obtain net radiation absorbed from sun. The radiation reflected by the floor and absorbed by the glass surface is neglected because its effect is small (about 10%) as described in [1]. Another assumption used is that the radiative heat transfer between various glass surfaces is negligible. This assumption prevents accounting for 28 possible heat transfer combinations of the control volumes. In reality, there will be slight temperature differences between various glass surfaces but is expected to be less than 5 K.

For radiative heat losses to outside, sky temperature is calculated by equation mentioned in [3]. Radiative heat transfer block from Modelica standard library is used to model this heat transfer.
For the floor, the energy equation can be written as:

$$\rho_f c_f \frac{dT_f}{dt} = q_a^r - q_e^r + q_i^{co} - q_o^{co}$$

The absorbed radiative heat transfer portion represents the radiation which gets transmitted through various glass surfaces and gets absorbed. In the real case, the transmitted radiation each glass surface undergoes multiple reflections on other surfaces or even gets reflected to outside the greenhouse. For the purpose of modeling, it is assumed that 60% of the radiation coming in from various surfaces will get absorbed into the floor. The absorptivity of opaque surfaces making the floor is typically in the range of 0.8 – 0.9 while reflectivity of glass is about 0.1 and transmissivity 0.85 [4]. Thus 10% of radiation falling on each glass surface gets reflected, 85% of which gets transmitted in and 80% of which gets absorbed into the floor (0.9*0.85*0.8 ~= 0.6). The radiation emitted to the glass surfaces is modeled using the radiation block. View factors from floor to walls equals 0.18, while from floor to each of the roof = 0.14.

The heat transfer by convection is modeled similar to the glass surface. Since the house is raised over a platform the heat losses term to the outside air is also modeled.

Lastly, to model the air inside the courtyard the energy equation is as follows:

$$\rho_a c_a \frac{dT_a}{dt} = q_s^{co} + q_g^{co} + q_{\inf}$$

The absorption of radiation in the air is neglected. This is a very common assumption in greenhouse modeling [1,2,4]. The first term on the right hand side is the convective heat transfer from soil, second term is convective heat transfer from glass surfaces while the final term is infiltration. The heat transfer from the air coming in by infiltration is calculated as:

$$q_{\inf} = \rho_a c_a V * \frac{ACH}{3600} * (T_{in} - T_{out})$$

ACH was set to 7 since the courtyard is not as tightly sealed.
This model was implemented in Modelica, and some of the preliminary results of this effort are shown below. These plots help validate the concept of the sunspace as a solar collector, showing how the space can be used to help moderate between the indoor and outdoor conditions. This will not only facilitate the use of this unconditioned space for indoor activities throughout the year, but will also improve the overall energy efficiency of the house.

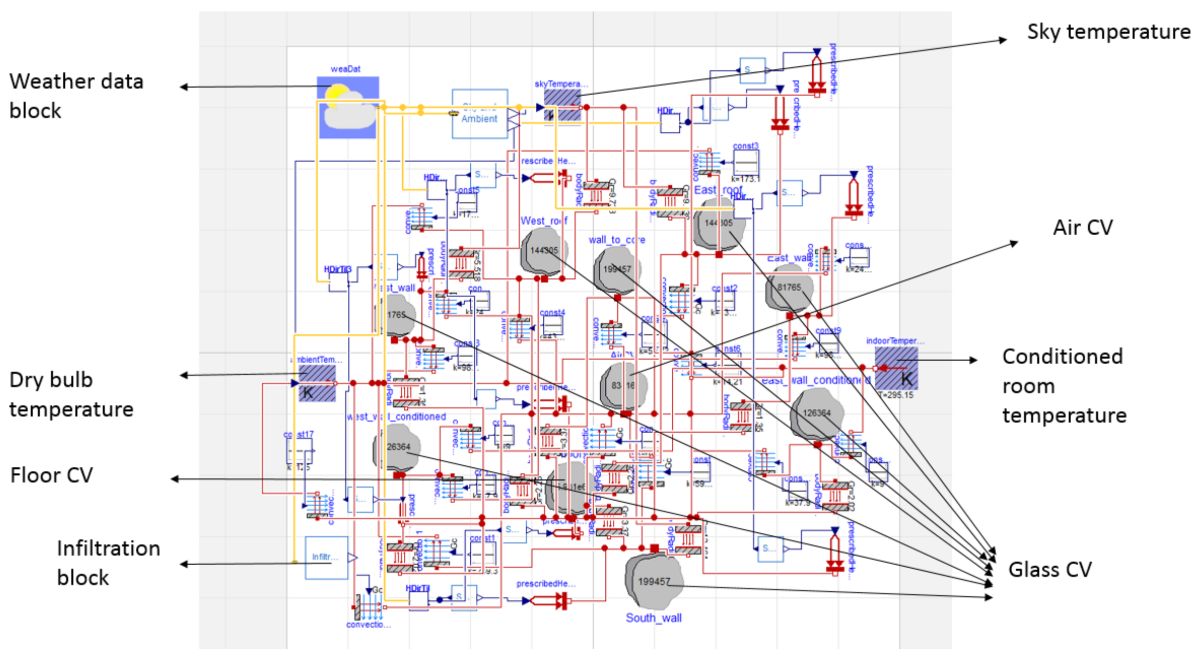


Figure 3: Modelica GUI for Courtyard model

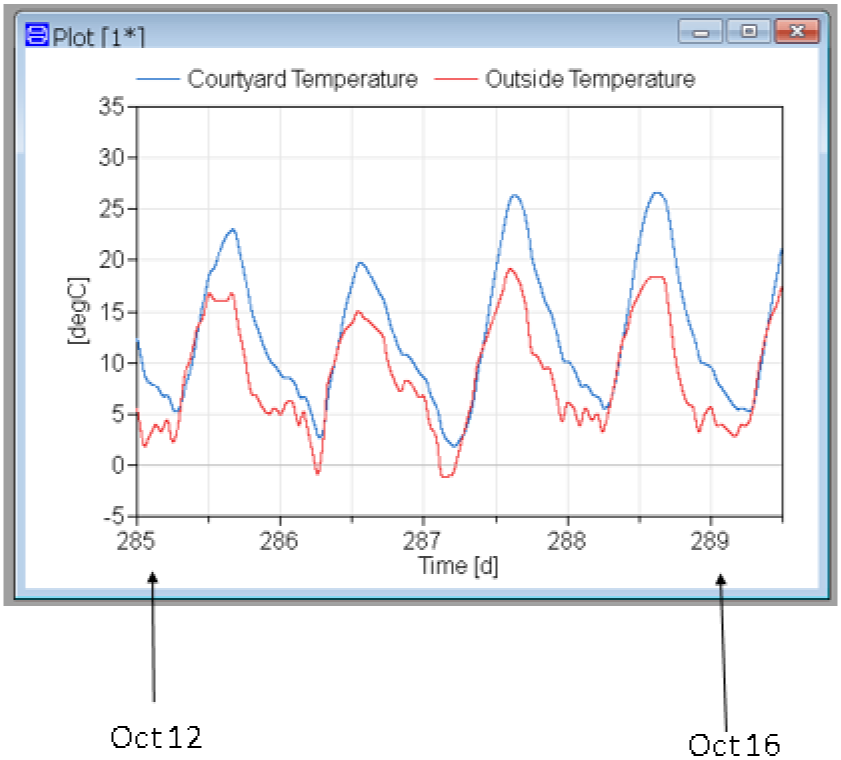


Figure 4: Courtyard temperature vs outdoor temperature near competition dates

This model is still being developed, adding the effects of shading and insulated shades for better thermal control. This model will be used to plan control strategies to determine how the Courtyard should be configured for different weather conditions. It will also be integrated with the EnergyPlus model (described below) to allow for integrated simulation of the entire design and not just the conditioned space.

References

[1] Joudi KA, Farhan AA. A dynamic model and an experimental study for the internal air and soil temperatures in an innovative greenhouse. *Energy Convers Manag* 2015; 91:76–82

[2] Abdel-Ghany AM, Kozai Toyoki. Dynamic modeling of the environment in a naturally ventilated, fog-cooled greenhouse. *Renewable Energy* 2006; 31:1521–39.

[3] Swinbank WC. Long wave radiation from clear skies. *Q J R Meteorol Soc* 1963;89:339.

[4] Bouadila S, Kooli S. et. al. Improvement of the greenhouse climate using a solar air heater with latent storage energy. *Energy* 2014; 64:663-672

Energy Modeling with Revit / GBS

In order to model not just the form of the building, but also the specific placement of fenestration and the zoning of the spaces, it will be necessary to use more detailed modeling tools (more control than BEOpt allows). Revit was used to model the house and prepare the Construction Documents, but it can also be used with plug in tools like Green Building Studio (GBS) to analyze energy use.

One of the initial uses of Revit models was to investigate different building forms (massing studies). Four options that were studied are shown below.

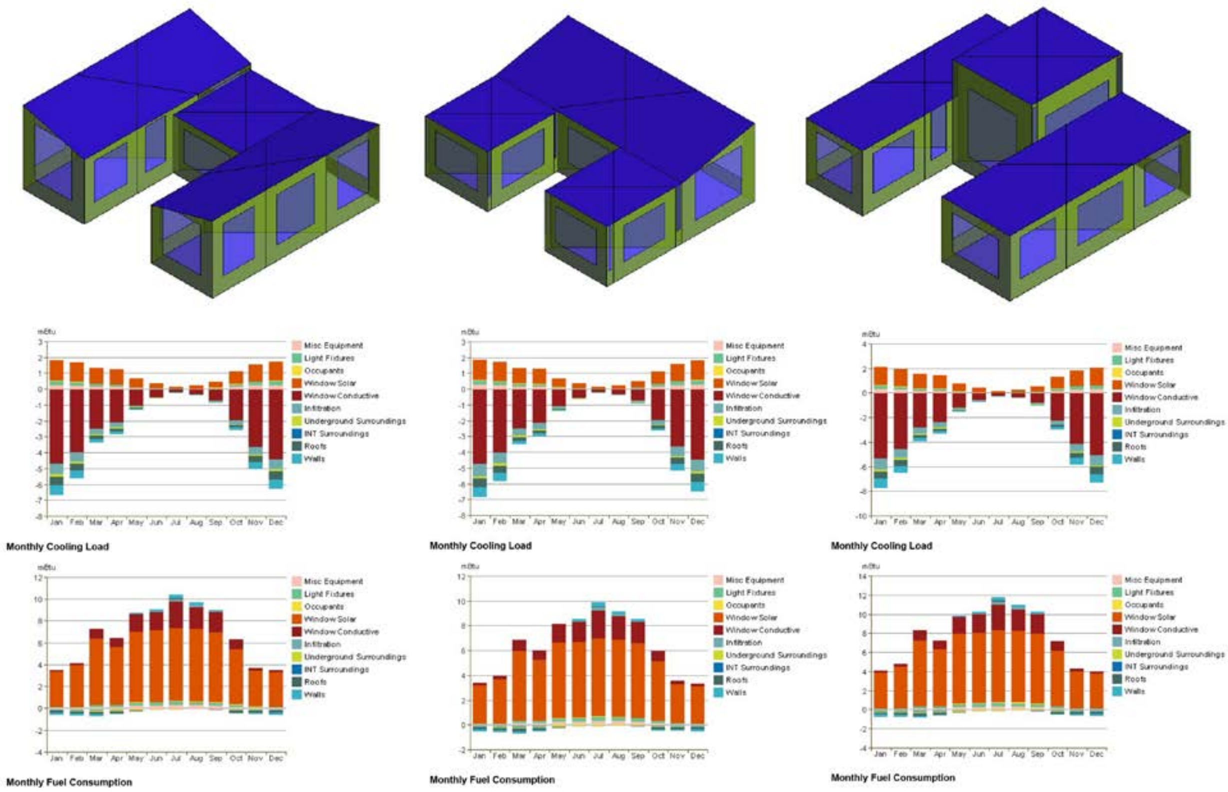


Figure 5 – Revit Green Building Studio Sample Output for 3 house massings

This is a relatively simple example, but the Revit model is nearly complete and there are plans to simulate the entire building, including Courtyard using this tool.

Energy Modeling with OpenStudio / Energy Plus

In order to integrate the model of the Courtyard greenhouse, as well as the advanced control features developed by the Maryland Team, a more flexible simulation environment is required. EnergyPlus was selected for its open non-proprietary architecture. OpenStudio is an extension to the popular Google SketchUp software that facilitates the construction of the building geometry and properties definition. The current model of *reACT* is shown below, along with preliminary simulation results. These results still do not include the model of the greenhouse described above, which is still being developed for integration with EnergyPlus.

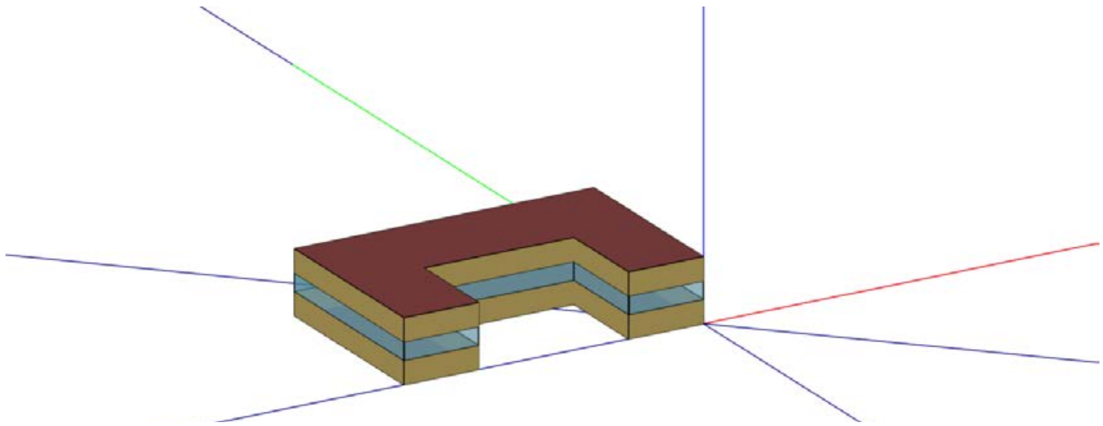


Figure 5: Preliminary Sketch-up Model

Figure 6: Energy Consumption Breakdown (Open Studio)

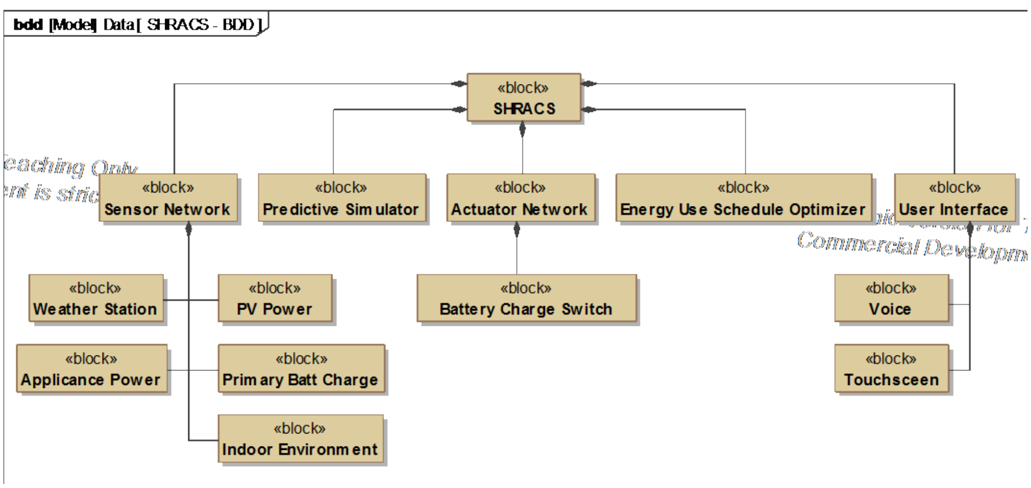
Table 3: Energy Consumption Summary

End Use	Consumption (kBtu)

Heating	22,046
Cooling	3,014
Interior Lighting	10,796
Interior Equipment	7,867
Fans	2,227
Water Systems	60,329
Pumps	95

Model Based Control

To implement the model-based control system described previously, it was also necessary to develop a simplified, but physically based, model that could run in real time. This model is a key element in the house environment and energy management supervisory control system that is under development. This control architecture was chosen to provide maximum fault tolerance, to be minimally invasive, and to provide maximum flexibility with regard to future upgrades. Called SHRACS (Supervisory home resource allocation control system), the predictive



simulator can be seen in the block diagram below.

Figure 7: Supervisory home resource allocation control system

Python was selected as the best language to implement this simulation, given its object-oriented nature and the ease with which it interfaces to web-based applications, including our weather prediction module. Over the past several months, the physically based control system model has become increasingly sophisticated; it represents a *virtual house* that we can use to study the impacts of different weather conditions and control decisions on the operation of the house. The Maryland Automation Team is preparing to 'go live' with the simulation, posting the performance of the virtual house to the Team's website for visitors to investigate and learn about *reACT*.

The physically based model does not include the advanced model of the Courtyard Greenhouse described above, but this innovation is being integrated for study in the near future.

Output from the SHRACS is shown below. This represents a nominal day for the date shown, with *predicted* PV array power shown in the top and anticipated power-consuming events as negative values in the upper plot. The latter are color-coded as fixed (blue) and movable (green) events – the large green (movable) block corresponds to charging the family EV. Total energy use/production is shown as the green curve, indicating net positive energy production.

The lower plot represents the economic analysis of the power production/use schedule for the day based on the rate schedule posted in the SD rules. Again, the green curve is the cumulative value, showing a net loss in profit for that day's scenario.

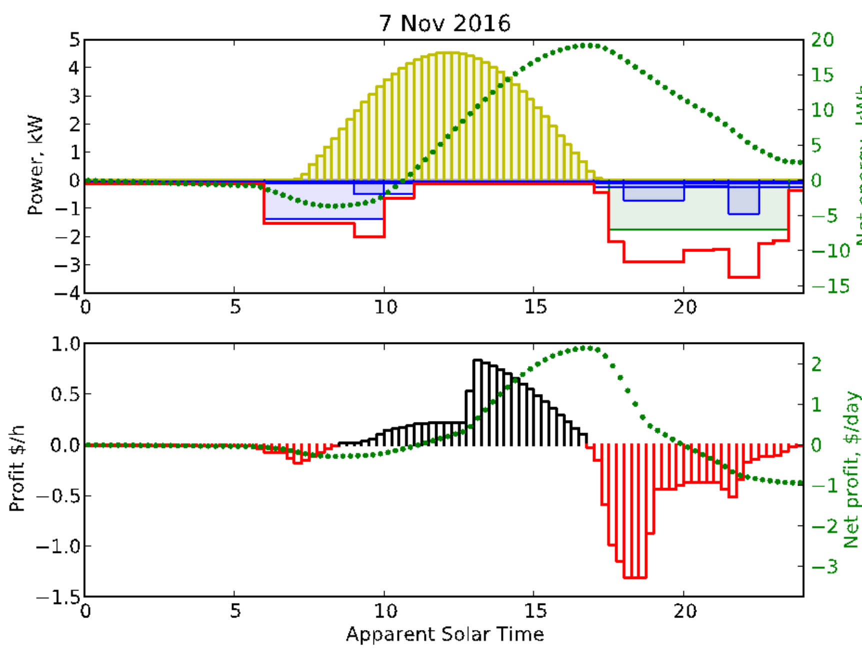


Figure 8: Projected user case scenario for energy usage and cost

Given our control system's emphasis on scheduling resources, we now show that the simple shift of charging the family EV from the early evening to early morning does not affect the net energy balance; however, the economic impact is significant, with the second scenario resulting in a net profit for the family. These results are shown in the plot below.

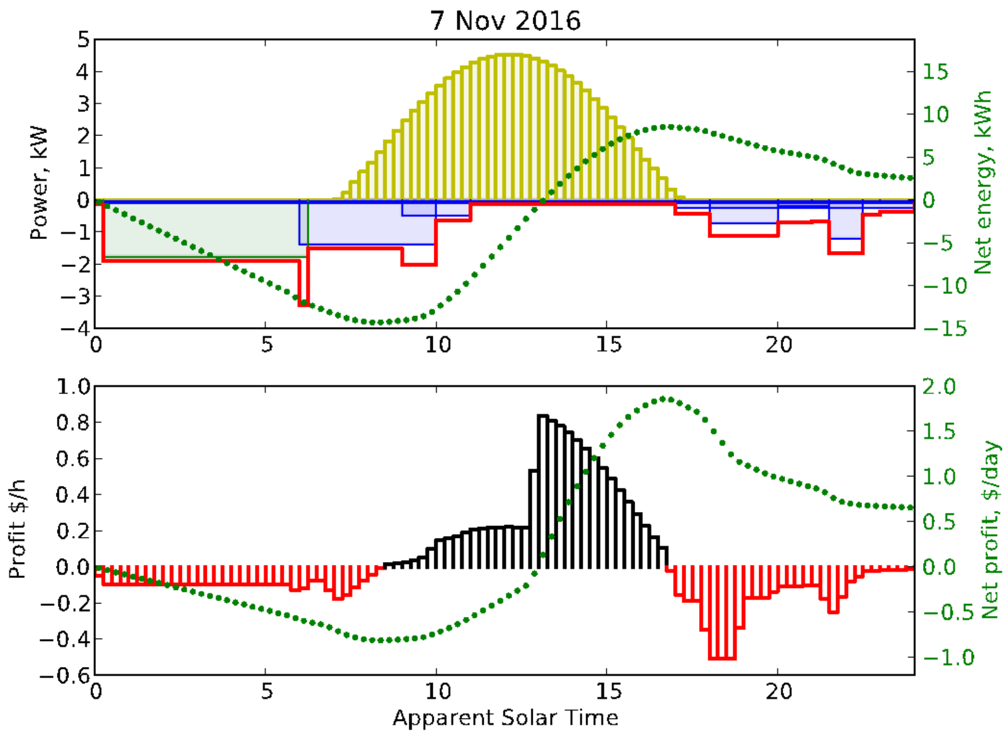


Figure 9: Projected energy usage and cost after shifting movable peak load

Energy Modeling Summary

The multiple models described above illustrate Maryland's approach to energy modeling in SD2017. Different modeling tools are used at different phases of project development as makes most sense. The Maryland Team intends to continue streamlining this process to ensure continuity of model fidelity as new capabilities are added.

Water Budget

The water treatment system within the house is a key component of the reduction in water usage overall. For the competition, we will collect light greywater from sources such as the bathroom shower and sink, as well as rainwater and run the water through a series of filters and treatment methods such as UV. The light greywater will be filtered through multiple Bio-sand Filters and then combined with collected rainwater, before the combined water is sent through a series of carbon and ceramic filters before passing through a UV treatment light to kill pathogens, before ultimately being sent to a holding tank for future irrigation.

The treated water will not be hooked up for recirculation during the competition, and is therefore an open system rather than a closed system. During our competition duration, the treated water's end-use is for the courtyard's irrigation system. However, the house has been designed to send the water to both irrigation as well as for potable reuse in the entire water system after additional treatment. This potable standard will be tested next summer to verify our ability to have a closed system within the house.

FUNCTION	WATER USE (GALLONS)	CALCULATIONS GALLONS EVENTS		NOTES
CLOTHES WASHING	67.35	13.47	5	WASHING LAUNDRY
HOT WATER DRAWS	210	15	14	DELIVER IN LESS THAN 10 MINUTES, @ LEAST 110 F
COOKING	3.6	0.6	6	5 LB OF WATER VAPORIZED
HUMIDIFIER	45	5	9	CONSTANTLY RUNNING
HOT WATER TANK	50	-	-	NOT COUNTED IN REQ. WATER
FIRE PROTECTION	250	250	1	IN CASE OF FIRE

IRRIGATION	N/A	-	TBD	TAP FROM GREY WATER TANK

CALCULATED TOTAL = 575.95 GALLONS
SAFETY FACTOR = 10%
WATER REQUIRED = 633.545 GALLONS ~ **635 GALLONS**

***LANDSCAPE AND ECOLOGICAL SYSTEMS WILL BE DETERMINED IN TERMS OF THE WATER THAT IS NEEDED, BUT THE IDEA IS TO WITHDRAW WATER FROM THE GREY WATER TANK TO IRRIGATE THOSE SYSTEMS AND ***FIRE SUPRESSION MAY BE TAPPED FROM THE POTABLE WATER TANK

BOTTLED WATER DOESN'T PLAY INTO THE WATER BUDGET

Health & Safety Approach

Maryland will take every possible precaution to ensure the health and safety of students, faculty and visitors during construction, transportation, assembly, disassembly and operation of the house. Two students and three faculty members (as identified below) will complete the 30 hour OSA Training, and will be charged with ensuring proper procedures and equipment are used throughout the project. At least one of these individuals will be present at all times when work is being performed, both at the campus construction site and at the competition site.

In addition to training for these health & safety leaders, all students and faculty that will be working regularly on site will receive a one to two hour training course provided by the University of Maryland. No one will be allowed to use equipment such as power tools without first demonstrating appropriate knowledge and awareness regarding safe use of that equipment. Individuals performing work at roof level or on scaffolding will be protected by safety harnesses. Hard hats, safety glasses, gloves and appropriate footwear and clothing will be required at all times. Fire extinguishers, first aid kits and other first on-site responder equipment will be conveniently located and accessible at all times (and all personnel on-site will be made aware of their locations).

Individuals Receiving 30-Hour OSHA Training

Project Manager – Michael Binder.
Lecturer in School of Architecture, Planning and Preservation.
mbinder@umd.edu

Student Project Architect - Sandra OhBoun

Student Project Architect - Deputy Malik Johnston-Williams

Construction Manager – Garth Rockcastle.
Professor – School of Architecture, Planning and Preservation.
gcr@umd.edu

Student Construction Manager- Alla Elmahadi

Student Construction Manager – Deputy Christiane Machado

Student Health and Safety Officer – Sophie Habib

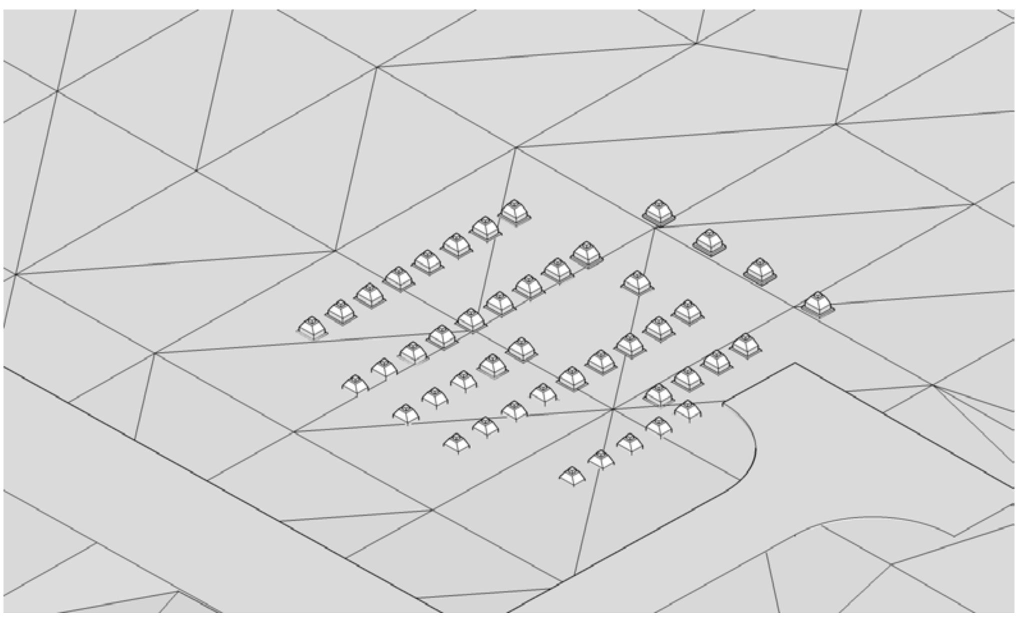
Student Health and Safety Deputy – Anil Moore

Structural Design

Structural System Narrative

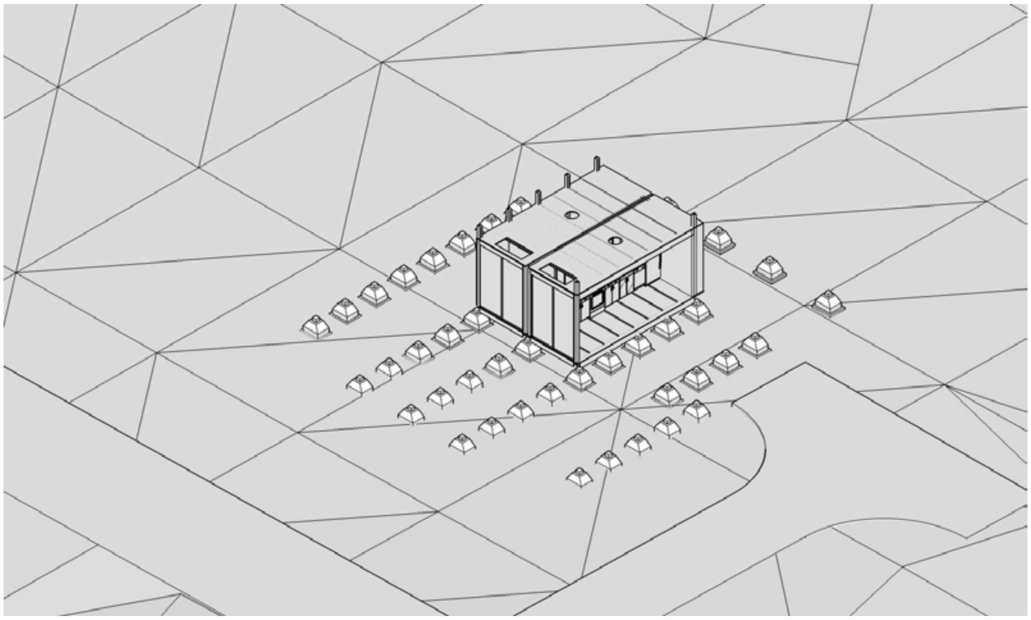
The 2017 Maryland house will employ an innovative modular structural and enclosure system which integrates aluminum frame with composite honeycomb SIPs. The aluminum frame also serves as a conduit for distributing power and refrigerant lines throughout the house. The structural system was developed not for a single incarnation as the SD2017 entry, but as part of the genetic code for a diverse new housing *type* – modular regenerative dwellings. This structural system was selected for its potential to facilitate construction of a wide range of different building forms.

Assembly starts with placement of ballasted footings with adjustable screw jacks. These will be located and adjusted using laser leveling devices to accommodate variations in site topography.



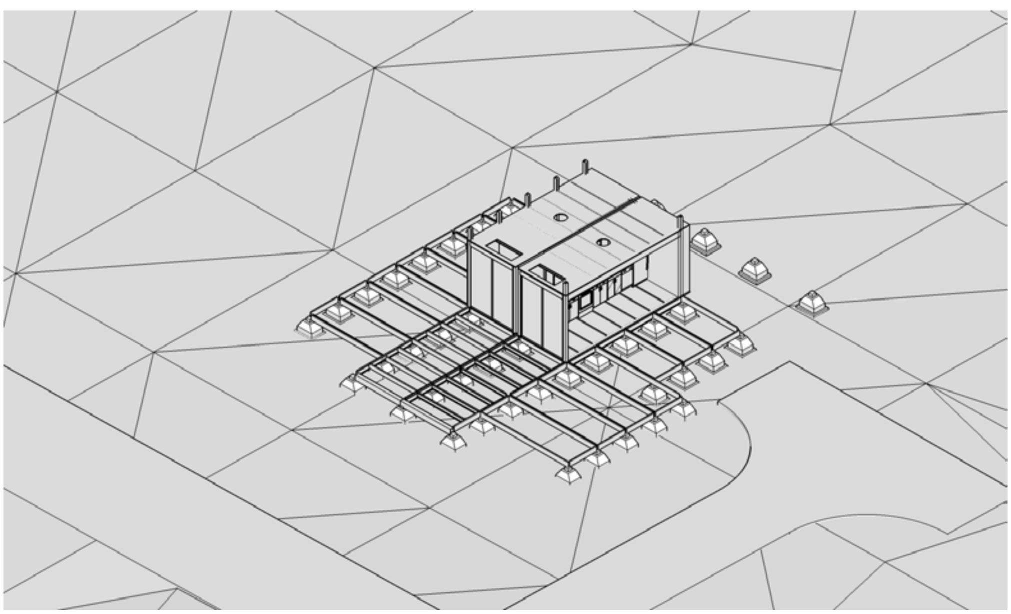
3D model of footings

Once the footings are in place, the prefabricated modules comprising the Core of the house are craned into place and secured together and to the footings. These modules are preframed and structurally independent, including shear reinforcement

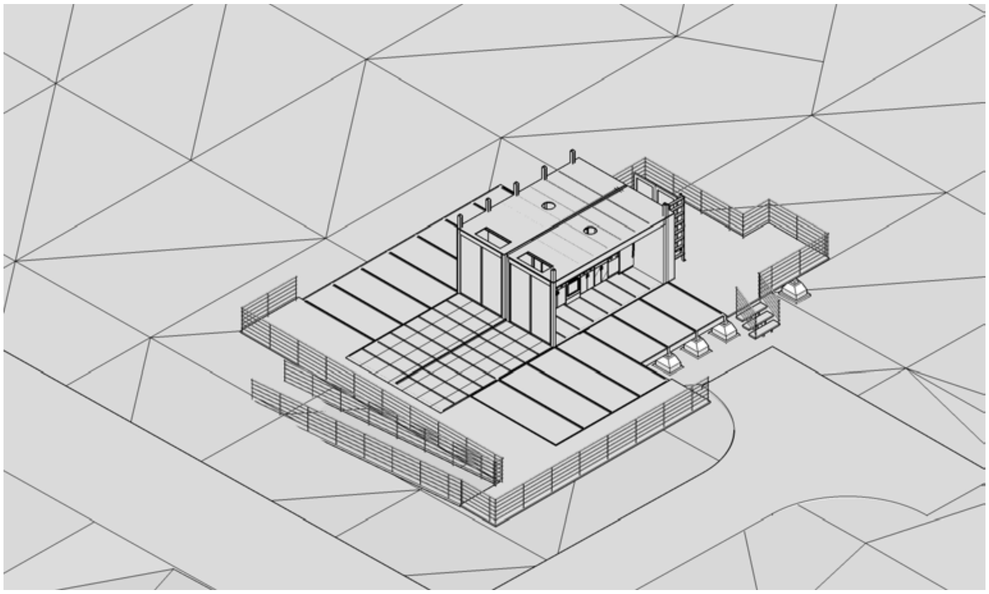


3D view of modules with framing shown.

The floor deck, composed of wood framing and composite SIPs panels will be assembled around the prefab Core, placed on the foundations and bolted together, as well as being bolted to the footings. This forms a stable platform for assembly of the rest of the building. In its final incarnation on a client site, this platform might rest on foundation walls or might be replaced by slab on grade.

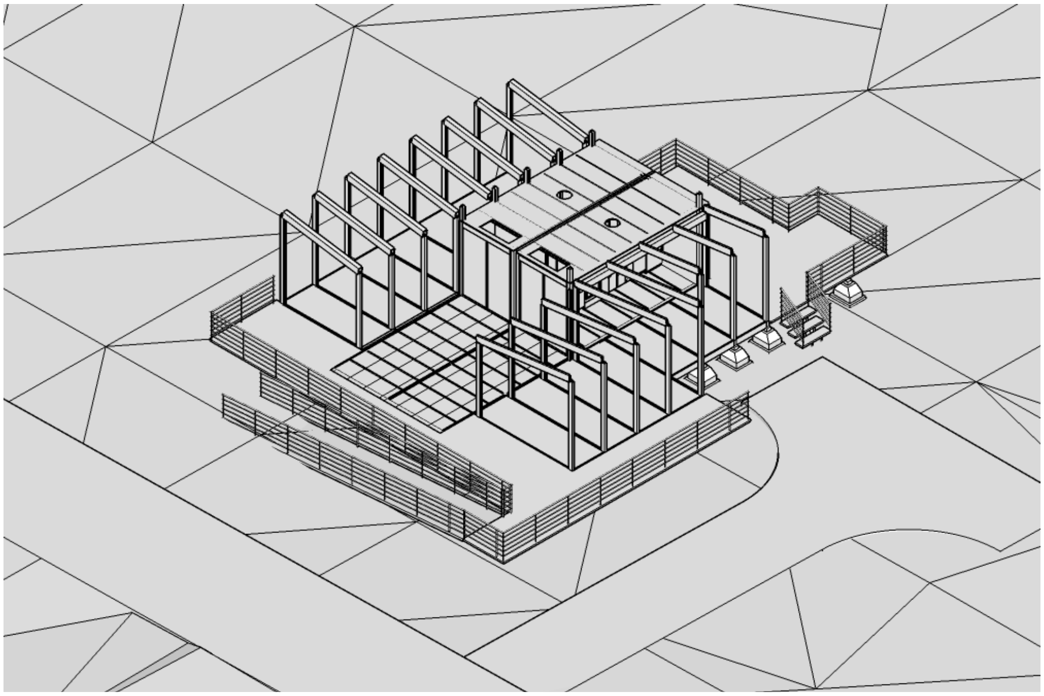


3D model of footing attachment to floor framing members.



3D model of the completed floor structure

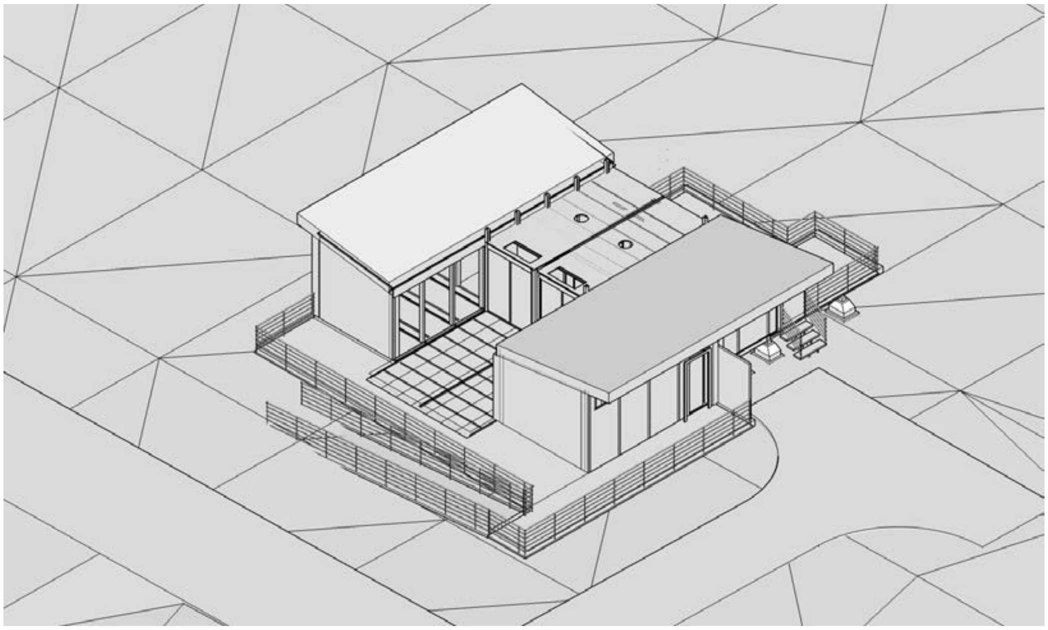
Next the footings for the decking are located and leveled. Prefab sections of ramp and decking are attached to the footings and at strategic intervals to the house, which provides additional stability. The aluminum frame is assembled next. The frame may be prewired with power and refrigerant lines to facilitate quicker assembly. Columns are bolted to the platform, which carries appropriate blocking to transmit vertical loads directly to the foundations below and into the ground. Aluminum beams and joists are attached to the columns using custom hardware and bolted in place.



3D model of the completed frame.

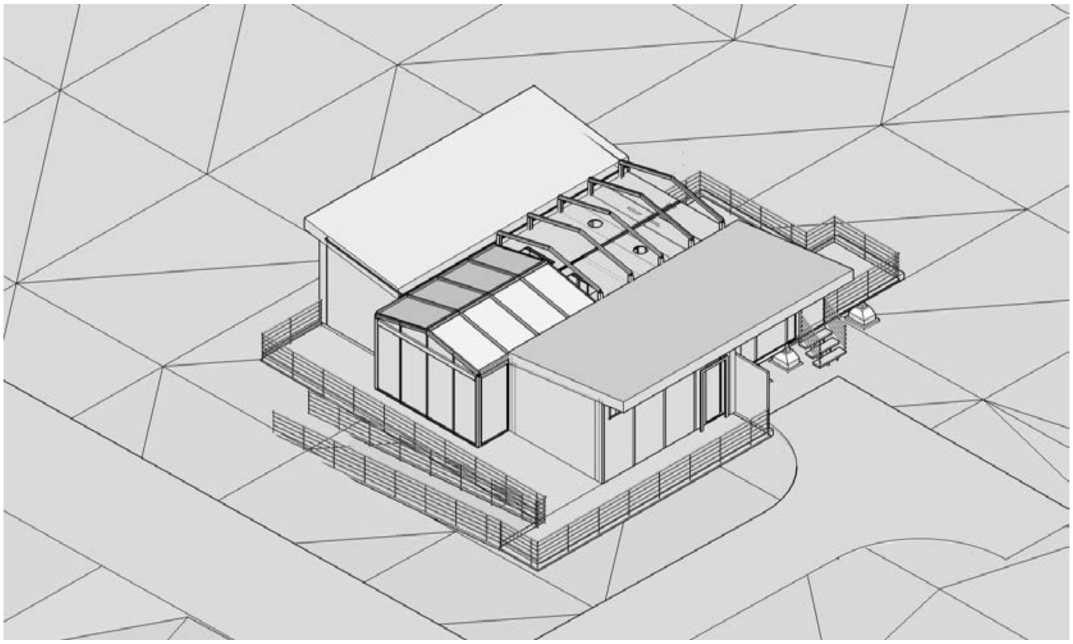
The aluminum frame include special snap connections, thermally broken. The Maryland house will demonstrate an innovative quick connection and disconnection hardware for attaching SIPs to the frame. The composite wall panels are lifted into place and snapped securely to the columns, stiffening the frame and adding lateral reinforcement. Windows are either prefabricated parts of these composite panels or in some cases are substituted for the panels. Roof panels are similarly snapped onto the beams, creating the roof diaphragm and completing the basic structure of the house.

2D details of panel attachment to columns and beams.



3D view of the completed walls

Next the greenhouse Courtyard is assembled and attached to the completed house as described above. The aluminum beams and joists of the Courtyard floor are secured to the footings and to the house via thermally broken bushings bolted through the envelope. The aluminum columns are built on top of this floor frame and bolted to the columns of the conditioned space. A spare but functional roof frame is attached to the columns, along with tie rods to prevent spreading of the walls caused by roof loads. Glass panels (in aluminum frames) are attached to the frame, stiffening the structure and adding lateral stability, though much of the lateral strength is derived from its attachment to the house.



3D view of the greenhouse frame

This completes the structure of the house and courtyard.
As the attached calculations demonstrate, the weight of the house provides the required uplift, overturning and sliding protection required, without the need additional anchorage to the ground. As indicated in the Specifications, the composite SIPs panels provide ample strength and stiffness for the floors, roof and lateral stability of the structure. All aluminum frame components are protected by materials with a 1-hour fire rating, as well as an automatic sprinkler system.

Structural Professional Acknowledgement Letter

The University of Maryland Team is currently negotiating for the services of a licensed Professional Engineer.

Structural Calculations

Structural Calculations are currently incomplete.